23. Non-Conventional Electricity Sources for Motor Vehicles

Sponsors:
MIT/Industrial Consortium on Advanced Electrical/Electronic Components and Systems, Toyota Motor Company

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This research is being carried out in the MIT Laboraotory for Electromagnetic and Electronic Systems in collaboration with the NanoStructures Lab (NSL). Its focus is the development of a thermophotovoltaic (TPV) power conversion system for auxiliary electric power generation in automobiles, and other potential applications. The TPV system, illustrated in Fig. 1, harvests the photons radiated from the emitter and converts them into electricity by means of a photovoltaic (PV) cell. Because it has no moving parts, the system is amenable to quiet, low-maintenance operation and a long lifetime.

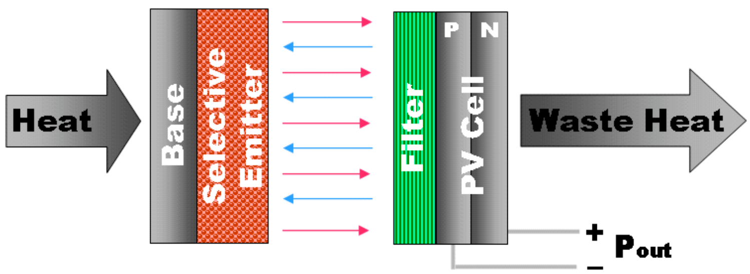


Fig. 1. TPV power conversion system with spectral control components.

Current TPV systems exhibit radiation-to-electricity efficiency of only 12%. In order to compete with conventional alternators, TPV systems will have to demonstrate efficiencies of approximately 40%. Previous research has indicated that effective spectral control is the main factor in increasing the efficiency of a TPV system (Fig. 2).

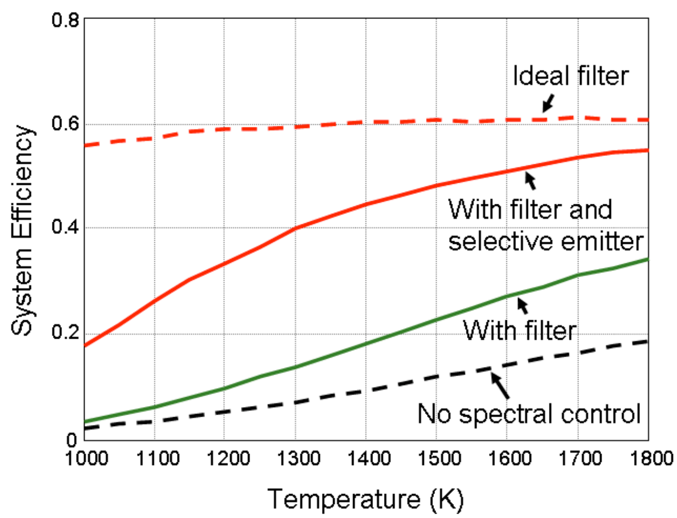
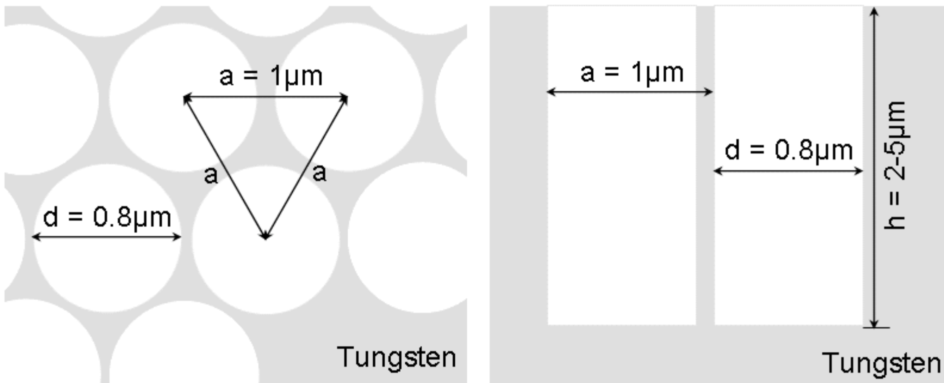


Fig. 2. Efficiencies of TPV systems with various spectral control options.

The spectral control components in a TPV system protect the PV cell from undesirable low-energy photons that cannot be converted into electricity. Besides protecting the PV cells from undesirable radiation, the filter also provides for energy recycling on the emitter side. The design, fabrication and characterization of the filter for the MIT-TPV system have been completed with excellent results [1].

The part of this project carried out at the NSL is the development of the selective emitter; a two-dimensional photonic crystal. The pattern arrangement for this crystal is a hexagonal array of round holes. The specifications for the dimensions of the structure are given in Fig. 3. Because of natural variations in tungsten's refractive index, this transition metal is particularly suitable as the substrate for our selective emitter.



a) b)

Fig. 3. Dimensions of the selective emitter structure to be produced in tungsten: a) top view; b) cross-sectional view.

The patterning for this structure is done using the Lloyd's-mirror interference-lithography system in the NSL, using a 325nm wavelength HeCd laser. The pattern is captured using THMR-iNPS4® negative photoresist on top of BARLi® anti-reflective coating (ARC). The pattern is developed using CD-26. At this point, a double hard-mask is used for the process. Silicon dioxide is used as the mask for the underlying chrome layer, which in turn is used as the mask for the underlying tungsten. The ARC and SiO_2 etches are done using RIE He/O_2 and CF_4 chemistries, respectively. The Cr etch is done using commercially available CR-7 wet etchant.The current stage of the project is the calibration of the Cr etch. The goal of the project is to perform integrated testing of a TPV system with both types of spectral control.

TPV systems have great potential to be used as power generation systems in automobiles. In order to do so, they must achieve efficiencies comparable to modern alternator efficiency. Proper spectral control can satisfy that requirement, and therefore make the TPV systems the clean, quiet and low-maintenance power generation system for automobiles.

[1] Francis O'Sullivan, "Fabrication and Testing of an Infrared Spectral Control Component for Thermophotovoltaic Power Conversion Applications," M.S. Thesis, Department of Electrical Engineering and Computer Science, MIT, June 2004.